

**Seasonal to Decadal-Scale Variability in Satellite Ocean Color and
Sea Surface Temperature for the California Current System**

FINAL REPORT
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ABSTRACT

This project was initiated under NASA Headquarters support for the Ocean Color Science Team. A three year grant (NAG5-6559) was augmented with a one year merit-based extension (NAG5-10276). The intent to extend was initiated by NASA HQ management to spread the Ocean Color funding cycles across multiple years. This represents an overall final report for the 4 year funding period. Some publications cited in the below originated in an earlier granting period, but we list only those publications starting in calendar year 1999 that acknowledge funding for support under NASA's Ocean Color Science team.

Support for this project was used to develop satellite ocean color and temperature indices (SOCTI) for the California Current System (CCS) using the historic record of CZCS West Coast Time Series (WCTS), OCTS, SeaWiFS and AVHRR SST. The ocean color satellite data have been evaluated in relation to CalCOFI data sets for chlorophyll (CZCS) and ocean spectral reflectance and chlorophyll OCTS and SeaWiFS. New algorithms for the three missions have been implemented based on in-water algorithm data sets, or in the case of CZCS, by comparing retrieved pigments with ship-based observations. New algorithms for absorption coefficients, diffuse attenuation coefficients and primary production have also been evaluated. Satellite retrievals are being evaluated based on our large data set of pigments and optics from CalCOFI.

We have determined mean values temperature and chlorophyll for the region and sub-regions, which are being evaluated compared to the signals observed from satellite for the 1982-1983 and the 1997-1998 El Niño events. The regional indices we have developed are being compared to standard Southern Oscillation Indices (SOI) generated by the National Center for Environmental Prediction (NCEP) or other regional indices of physical climate forcing. We hypothesize that the SOCTI correlation and time lag relative to various SOI indices will allow predictions of the response of the CCS ecosystem to seasonal to interannual physical climate variability. Evaluation of those hypotheses will await the future cycles of El Niño.

In the past year of extended funding we focused on three new research directions that built upon the tools that we developed in the first three years of funding. These tools have been applied to the time series of primary productivity in the California Current during the El Niño cycle of the late 1990's, satellite ocean color and sea surface temperature time series of the Gulf of California, and evaluation of SeaWiFS chlorophyll retrievals for the Southern Ocean. We have four new articles submitted on these topics to peer reviewed journals that were supported with the 1-year extension.

Project Description

To accomplish the objectives of the program will first require the development and application of product algorithms to estimate pigments and water clarity (attenuation coefficients) from satellite data, validation of the products and specification of the error fields. Once products are validated and the error estimates are known, the satellite ocean color products must then be related to both large scale and small scale physical forcing of the ocean systems of interest. For example it is of great scientific value to quantify the effect on surface chlorophyll and primary production observed during the period from the late 1970 through the present when significant decadal scale and strong interannual signals influenced the California Current System (CCS). The West Coast Time-Series (WCTS), processed and available from NASA JPL is one of the best resolved in terms of temporal coverage of CZCS LAC data, but interpretation of that data set is limited by known issues with processing algorithms and calibrations. Application of advanced algorithms and processing schemes at LAC resolution will allow improved

scientific use of the CZCS WCTS. Before using new algorithms or models for derived products to evaluate satellite time series, the accuracy of the retrievals must be specified so one can be assured of discriminating noise of the retrievals from real signals in the time series. To do this well requires comparison with detailed *in situ* data sets. The frequent ship surveys of the California Cooperative Fisheries Investigations (CalCOFI) provides an excellent data set for validation in the CCS.

Simultaneously with our work on assembling the SST and Ocean Color Time-series, we are acquiring diagnostic indices of physical climate variability that are produced as part of the monthly Climate Diagnostic Bulletin of the National Center for Environmental Prediction (NCEP; <http://nic.fb4.noaa.gov>). NCEP products include anomalies for SST, winds, radiation, sea level pressure, etc. for the Pacific basin. Using conclusions drawn from the SOCTI response of the early 1980's to standard basin-scale diagnostic indices such as those available from NCEP, we will assess the power of the routine indices to predict the response of the modern satellite ocean color and SST time series for the CCS region during the massive 1997-1998 El Nino which has been followed by an equally dramatic La Nina. From 1998 through 1999 the CCS exhibited the largest positive and negative anomalies in satellite-derived SST relative to the long-term mean. This perturbation has been captured in detail by OCTS and SeaWiFS.

Accomplishments

During first the two years of this project we have published our results from data that had been collected during our NASA-sponsored SeaWiFS Science Team (previous grant NAGW-3665). This included contributing 30% of the data for NASA's chlorophyll algorithm (O'Reilly et al., 1998), in addition to regional-specific algorithms for the California Current for SeaWiFS standard products (Mitchell and Kahru, 1998) chlorophyll a (Kahru and Mitchell, 1999) and primary production (Valdez-Holguin et al., 1998). The baseline of CalCOFI optics supported by NASA from 1993-1996 allowed us to publish a novel paper on exploitation of the UVA region for developing ocean reflectance algorithms for red tide blooms (Kahru and Mitchell, 1998). All publications supported by the NASA SeaWiFS Science Team funding are listed in the publication list, and copies are included.

In the past year we have continued to apply our regional algorithms to analysis of CZCS, OCTS and SeaWiFS ocean color data for the analysis domain shown in Figure 1. The time series are being interpreted with respect to the NOAA AVHRR sea surface temperature time-series. Statistical analyses of the time series of primary productivity and zooplankton biomass were recently completed and have been accepted for publication (Kahru and Mitchell, 2002). From 1997 through the present, a massive El Nino – La Nina perturbation has occurred in the California Current system as exemplified by Figure 2 comparing SeaWiFS chlorophyll and AVHRR SST for May of 1998 and May of 1999. Productivity also had major perturbations. We also have extended our methods to satellite analysis of the Southern Ocean including assessment of the retrieval of chlorophyll from SeaWiFS (Holm-Hansen et al., 2002). We have concluded that SeaWiFS standard algorithms underestimates chlorophyll for much of the Southern Ocean and new algorithms are being formulated to address this issue. In the future we wish to continue our focus on algorithms for pigments and productivity in the California Current and Southern Ocean regions where we have strong collaborations with the CalCOFI and AMLR time-series ship surveys. The combine ship and satellite perspectives complement each other and allow for the most accurate applications of satellite data to studies of time-series at regional to basin scales.

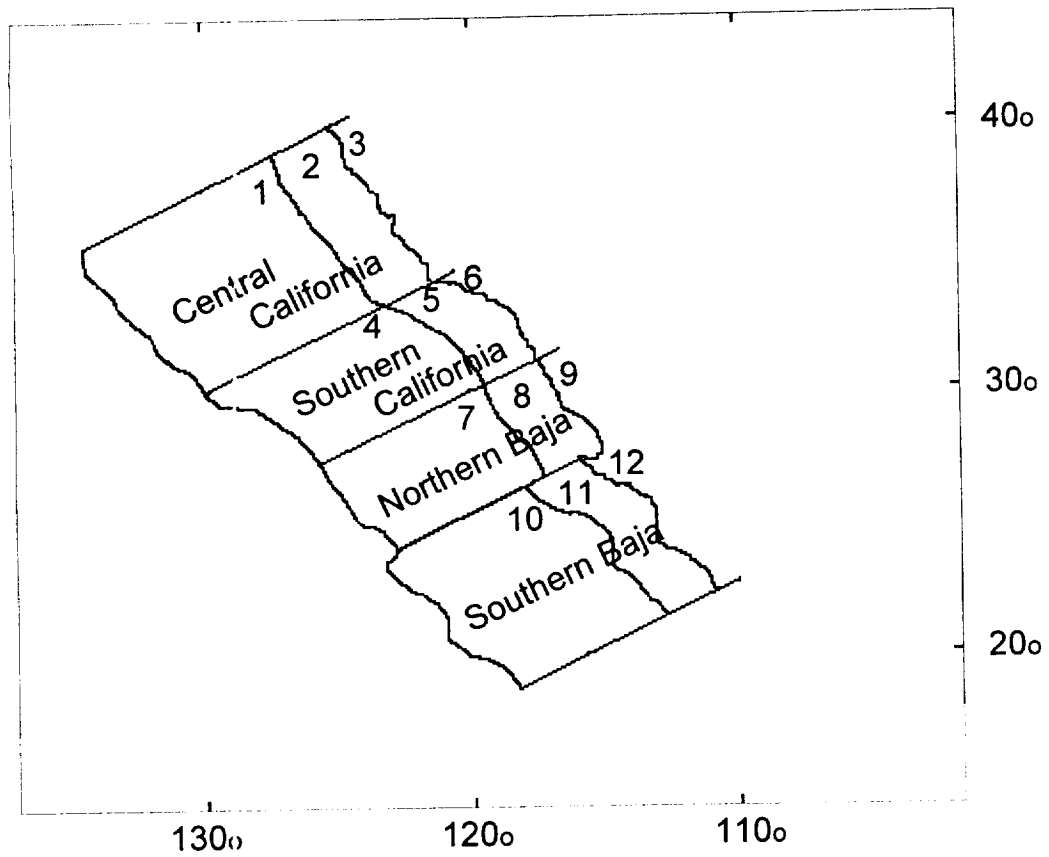
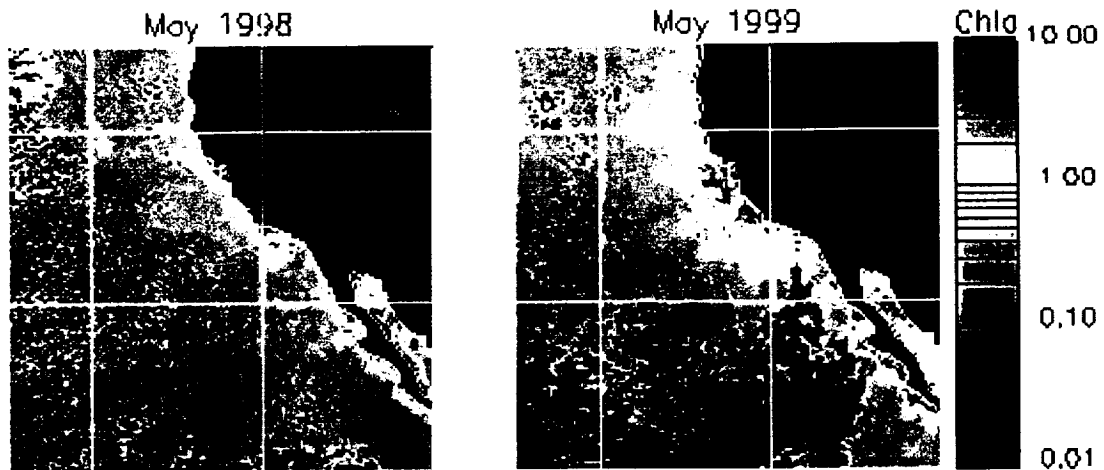


Figure 1. Regional domains of the California Current System used for statistical analyses. From Kahru and Mitchell (submitted)

SeaWiFS Chlorophyll a



AVHRR Sea Surface Temperature

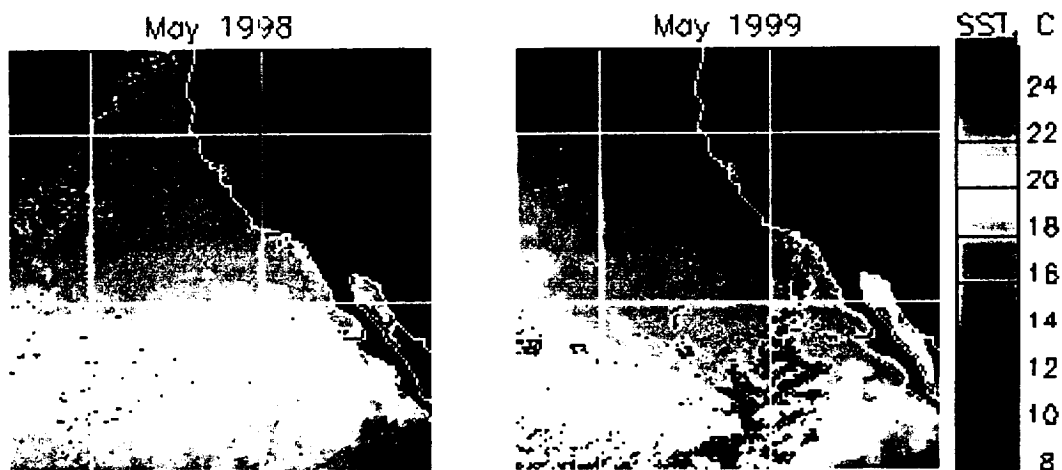


Figure 2. Comparison of surface chlorophyll and sea surface temperature for the California Current System in May 1998 and May 1999. Upper panel shows SeaWiFS-derived chlorophyll is much greater, especially in the Central California region, in 1999. Lower panel shows that the AVHRR SST Pathfinder sea surface temperature data are much warmer in May 1998 compared to May 1999. These data illustrate the strong influence of the recent El Nino – La Nina cycle.

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